

Influence of fly ash on soil characteristics of Kharland pond, Ratnagiri (Maharashtra)

Tekade AS^{1*}, Kulkarni GN², Mohite SA³

Research scholar, Dept. of Fishery Hydrography., Univ. of D.B.S.K.K.V, College of Fisheries, Ratnagiri, India
 Senior Lecturer, Dept. of, Fishery Hydrography., Univ. of D.B.S.K.K.V, College of Fisheries, Ratnagiri, India
 Senior Lecturer, Dept. of, Fishery Biology, Univ. of D.B.S.K.K.V, College of Fisheries, Ratnagiri, India

*Corresponding author: Research scholar, Dept. of Fishery Hydrography., Univ. of D.B.S.K.K.V, College of Fisheries, Ratnagiri, Mail: ankiocfsn@gmail.com

Received 26 August; accepted 16 October; published online 01 November; printed 16 November 2013

ABSTRACT

Fly ash is a powdery waste of coal-power generation and its management is a major environmental challenge. However, fly ash is useful ameliorant that may improve the physical and chemical properties of problem soil and is a source of readily available micro and macro nutrients. In the present investigation fly ash was incorporated in various proportions to study the influence on the acidic laterite soil on selected physico-chemical parameters. The seepage rate of soil was calculated by addition of fly ash with three different rates @ 25, 50 and 75%. While the maximum seepage was in control (100%) and minimum (25.33%) was observed in the soil with 75% fly ash. The physico-chemical properties of soil due to incorporation of different percentages of fly ash in soil were studied. Among the soil parameters the pH ranged from 4.40 to 10.05 in T₀ and T₃ respectively. The maximum bulk density of 3.69 gm/cm³ was observed in T₂ (50%). The maximum organic carbon 1.92% was observed in the T₀. The values of soil NO₃-N and PO₄-P ranged from 126 to 879 mg/g and 50 to 4780 mg/g in T₀ and T₃ respectively. The silicate content ranged from 4015 to 8334 mg/g in the treatment T₂ and T₃ respectively. ANOVA showed a significant difference among the treatments in all these parameters. The sodium content was noted higher in T₂ (6.53 mg/g) at the end of experiment. The potassium content ranged from 1.49 to 3.29 mg/g in T₀ and T₃ respectively. The iron and aluminium showed increasing trend at the end of experiment i.e T₃ > T₂ > T₁ > T₀. Based on the present study it was concluded that fly ash has major impact on the parameters like pH, EC, OC, bulk density, sodium, potassium, NO₃-N, Silicate-silicon, iron and aluminium.

Keywords: Flyash, Nutrient level, soil characteristics, seepage

To Cite This Article

Tekade AS, Kulkarni GN, Mohite SA. Influence of fly ash on soil characteristics of Kharland pond, Ratnagiri (Maharashtra). *Discovery Agriculture*, 2013, 1(2), 62-66

1. INTRODUCTION

Fly ash is a very fine powdery material produced as by-product during the coal based power generation process. It is a mixture of fine, spherical particles with size ranging between 0-100 microns. In an industrial context, fly ash usually refers to the ash produced during combustion of coal (Shrivastava et al., 2011). It is the residue of combustion of coal and comprises a wide range of inorganic particles, with low to medium bulk density and high surface area (Kumar, 2003). Fly ash is Ferro - aluminosilicate mineral with major elements like Si, Al and Fe together with significant amount of Ca, Mg, K, P and S (Aslam, 1998). Fly ash may often contain trace amounts of some heavy toxic metals like Molybdenum, Mercury, Selenium and Cadmium etc. Some metals enriched in fly ash include Cd, Cr, Ni, Pb, Al, Fe, Mn, Mg, Si and Zn while other has intermediate enrichment. The micro and macro nutrients present in coal get generally concentrated in the ash (Adriano et al., 1980). It is by virtue of this and the ability of fly ash to modify the physical properties of soils, it works as a soil conditioner enhancing the yield of the crops. India ranks fourth in the world in the production of coal ash as by-product waste after USSR, USA and China, in that order. About 120 coals based

thermal power stations in India are producing about 112 million tonnes fly ash per year (Alam and Akhtar, 2011). On account of its heterogeneous nature fly ash has the potential to be used as a soil-ameliorating agent in agriculture and forestry.

2. SCOPE OF STUDY

Few investigations on the influence of fly ash to improve agriculture soil from seepage and productivity have been attempted (Grewalet al., 2001; Mitttraet al., 2003, Deshmukhet al., 2006; Bhattacharya et al., 2011). Similarly, the soil from fish farm from Konkan and such area also needs to be investigated since major expenditure is incurred on the manuring of pond and replenishing the water lost due to evaporation and seepage. So the current investigation was undertaken with the following objectives.

- 1) To investigate soil characteristics from selected localities of Ratnagiri.
- 2) To determine the effects of flyash on the soil characteristics.

2.1. Materials

Table 1

Quantities of fly ash and soil mixed in homogeneous method

Treatment % FA	Quantity of flyash (kg)	Quantity of soil (kg)
T ₀ (Soil)	0	6
T ₁ (25%)	1.5	4.5
T ₂ (50%)	3	3
T ₃ (75%)	4.5	1.5

Table 2

Physical and chemical characteristics of the fly ash and soil prior to the experiment

Initial parameters of soil/fly ash	Soil	Fly ash
pH	6.07	11.07
Electrical conductivity (mmhos/cm)	0.24	1.55
Bulk density (gm/cm ³)	1.43	1.09
Organic carbon (%)	0.72	0.11
Sodium (mg/gm)	0.004	0.015
Potassium (mg/gm)	0.014	0.012
Iron (mg/g)	2010	0.71
Aluminium (mg/g)	2778	4.84
Nitrate-N (mg/g)	0.005	
Phosphate-P (mg/g)	0.030	
Silicate (mg/g)	654	

The Kharland ponds from the vicinity of College of Fisheries, Ratnagiri (Latitude 17°01'26.34"N and longitude 73°17'53.57"E) Maharashtra were selected for carrying out the research work. The soil samples were collected from four dyke corners of a pond and single composite sample was formed. Then the soil was analyzed for physico-chemical parameters. In the present research work the fly ash was procured from the thermal power plant located at Jaigad, about 40 km away from Ratnagiri. The fly ash was packed in to the large cartons and transported to laboratory. The dry fly ash was directly analyzed for selected physicochemical parameters.

2.2. Methodology

In the present experiment different quantities of fly ash and soil were mixed on weight basis to analyze the effect of fly ash on soil (Table 1). The required quantity of fly ash and soil were mixed homogeneously. Four treatments namely control (T₀), 25% FA (T₁), 50% FA (T₂), 75% (T₃) were taken with five replicates for 75 days. Seepage test was conducted by homogeneous mixture method (Table 1). Soil was mixed with fly ash homogeneously using selected proportions. The PVC column of 30-cm height and uniform diameter (9 cm) was used to know the quantity of water flowing through the soil. Fine mesh sized muslin cloth was tied at the bottom of the pipe and plastic bottle was used for water collection.

2.3. Sample analysis

The soil samples were collected from each replicate fortnightly during experiment in the morning at about 10 hrs. for the analysis of different parameters.

2.3.1. Soil sample physico-chemical parameters

pH was recorded with the help of digital pH meter. (Equipments, microcontroller pH meter model no EQ.621) with 0.01 precision. Bulk density was calculated as per Tondon (1993). The organic carbon content of sediment sample was determined by the method given by Jhingran et al. (1969). Electrical conductivity was measured with the help of EC kit by PHS - 3DpH meter CYBERLABTM. The phosphate, silicate, Nitrate-nitrogen content of soil sample was estimated following the procedure described by Tondon (1993).

2.4. Instrument used for metal analysis

2.4.1. Atomic absorption spectrophotometer

The AAS model used in the study for heavy metal level detection was AAnalyst 800 spectrophotometer system (AAS - Perkinelmer Analyst 800).

2.4.2. Preservation and digestion of samples

Dried soil sample was stored in cool/dark place in labeled polythene bags. The digestion of soil sample was done in Anton Paar Multiwave 3000 microwave digestion system. The digestion procedure required 2 hrs with pressure 25 bar 290 psi and temperature of 210° C. And further analysis was done on Atomic absorption spectrophotometer (Atomic absorption spectrophotometer Perkinelmer Analyst 800). The digested soil samples were aspirated to determine the content of metals namely Na, K, Fe, Al, Cu and Cd. Data obtained from the experiment was analyzed by one way ANOVA. Significant difference was indicated by P < 0.05. The Students Newman Kuel's multiple comparison tests was used to determine the significant difference between the treatments (Snedecor and Cochran, 1967; Zar, 2004).

3. RESULTS

The selected kharland pond soil was laterite in nature having reddish brown in colour. The initial values of different parameters of soil and fly ash are given in Table 2.

4. DISCUSSION

4.1. Effect of fly ash on soil characteristics

In the present study, the fly ash was found to raise the pH to 7.72, 8.49, and 9.62 in treatments T₁, T₂ and T₃ respectively over the control of 6.07 significantly. The increase in pH depends primarily on soil buffering capacity; soils that are poorly buffered are expected to show the greatest increase in pH after ash treatment (Zhakiet al., 2002). Fly ash is generally highly alkaline due to low sulphur content of coal and presence of hydroxide and carbonates of calcium and magnesium (Maitiet al., 2005). This property of fly ash has the effect to neutralize acidic soils (Elseewi et al., 1978; Phung et al., 1978). Page et al. (1979) observed during experiments with calcareous and acidic soils that fly ash addition increased the pH of the former from 8.0 to 10.8 and that of the latter from 5.4 to 9.9.

Electrical conductivity of soil increased gradually with increase in percentage of fly ash. The highest electrical conductivity was observed in T₃ (75%). It varied significantly between the treatments but there was no significant difference between the days. Kalra et al., (1997) also observed increase in EC of soil from 0.467 to 0.746 as the proportion of fly ash increased. Kishor et al., (2010) also found that the EC of soil increased with fly ash application relating this to Fe content.

Bulk density decreased in the treatment of 50 and 75% fly ash. Sale et al. (1996) observed that bulk density increased as fly ash addition increased to 25%, and then decreasing with additional fly ash. Karla et al. (1998)

Table 3
Effect of fly ash with different percentages on soil

Parameters	Treatments of fly ash			
	Control (T ₀)	(T ₁) 25%	(T ₂) 50%	(T ₃) 75%
pH	6.07	7.72	8.49	9.62
Bulk density gm/cm ³	3.36	3.60	3.63	3.31
Organic carbon (%)	0.69	0.85	1.67	0.44
Electrical conductivity (mmhos/cm)	0.327	0.446	0.574	1.137
Nitrate-nitrogen (mg/g)	158	305	476	658
Phosphate-P (mg/g)	443	2059	1179	2139
Silicate-Si (mg/g)	7446	6348	6762	6944
Sodium (mg/g)	4.38	5.41	6.53	5.52
Potassium (mg/g)	1.49	1.55	2.85	3.29
Iron (mg/g)	0.319	0.651	0.691	0.897
Aluminium (mg/g)	1.14	6.597	6.412	24.72

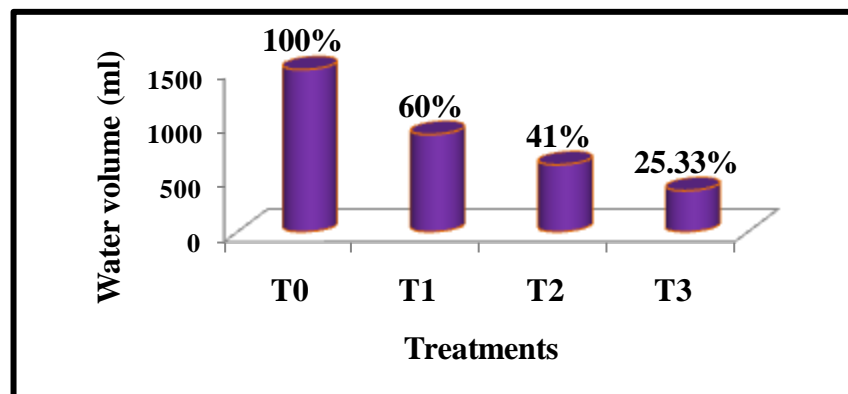


Figure 1
Effect on seepage rate

reported that fly ash addition to soil resulted in lower bulk density, although the differences compared with non-treated plots were not significant. The bulk density variation may be due to changes in the total porosity as well as modifications in pore size distribution as reported by Adriano et al. (1980) and Chang et al. (1977).

The highest organic carbon (1.67 %) was observed in 50% fly ash treatment. The marginal increase in OC content may be due to the fact that the soil initially had a very low OC content and it had not been supplemented with organic source (Prashanta et al., 2001). Kumar (2002) found that fly ash has its own carbon content i.e 0.11%. as it was applied to the soil having organic carbon 0.40%, it led to an increase in OC content by 0.55, 0.64 and 0.81 due to increase of fly ash proportion over the control (0.43%). Kalra et al. (2000) also observed that the OC value of soil-ash mixtures increased with ash content for sandy and sandy loam soil, whereas the reverse trend was noted for clayey and sandy-clay-loam soils. This can be attributed to relative changes in the soil texture.

The maximum PO₄-P content (2139 mg/g) was observed in the treatment T₃, whereas the minimum (443 mg/g) was in T₀. There was a significant difference among all the treatments. Phosphorous in soil increased as incorporation of fly ash increased, which can be attributed to fly ash itself and partly because of some native phosphate-solubilizers (Jala, 2005). Jala (2005) found that phosphorous increased in acidic soil as a result of fly ash amendment ranging from 254 to 1270 mg/g and reported that it may be due to an increase in population of phosphate-solubilizing bacteria observed with increasing fly ash percentage which was most favorable and also due to the presence of chemical fertilizers which augmented the nutrient supply for growth and proliferation of the bacteria by acting synergistically with fly ash. In acidic soil phosphorous though easily available as H₂PO₄ meets with interference from iron, calcium, magnesium compounds (Brady, 1995).

In the present work the maximum NO₃-N (658 mg/g) was observed in T₃ (75%) on 75th day, whereas, the

minimum (158 mg/g) was in T₀ on 30th day. ANOVA showed significant difference (P<0.05) in nitrate levels among the treatments. Effect of fly ash on soil nitrate showed an increasing trend in all the treatment between days. In T₀ it fluctuated (Figure 1 & Table 3). In the study made by Jala (2005) nitrogen content in the fly ash amended soil showed a significant increase ranging from 0.16 to 0.44 %. She reported that the native soil of Patiala was rich in nitrogen so the increased soil nitrogen can be attributed to decomposition of leaf litter, etc resulting in enzyme-aided nutrient mineralization carried out by the native microbial population. Nitrogen in soil is dominated by fertilizer-applied materials (Brady, 1995).

The maximum silicate (6944 mg/g) was in T₃, whereas, minimum (6348 ppm) was in T₁. It was also noted by Brady (1995) that silicate ranged from 1401 to 2712 mg/g markedly increasing with increase fly ash incorporation in acidic soil. This seemed to suggest that increase in silicate can be attributed to acidic pH and presence of silicate as a result of which SiO₃-Si increases in proportion to fly ash added. Na could associate with clays, which could account for their primary silicate distribution in fly ash (Kim and Kazonich, 2004).

In the present study small but consistent positive effect of fly ash application on available and exchangeable K was registered. The maximum concentration of potassium was 3.29 mg/g in T₃, while the lowest was 1.49 mg/g in T₀. Kumar (2002) found that potassium increased by 11.2, 15.3, 18.0 mg/gm as the incorporation of fly ash in soil increased over the control of 3.86 mg/gm. In fly ash available potassium is in small content and its addition in soil improves potassium level in the soil indicating the role of fly ash (Inthasan et al., 2002).

The initial sodium in soil was 0.004 mg/gm while in the fly ash it was higher i.e. 0.0014 mg/gm. At the end of experiment there was a significant increase in concentration of sodium from 4.38 to 5.52 mg/g in T₂. Similarly, Jala (2005) also found that sodium in soil increased as percentage of fly ash increased i.e from 11.1 to 54.8 mg/gm. Sodium in the coal may be precipitated from groundwater or infiltrating hydrothermal fluids, they are more likely to be associated with clays, which would account for their primary silicate distribution in fly ash (Kim and Kazonich, 2004).

The concentrations of iron and aluminium increased in soil as the percentage of fly ash increased. This is due to the fact that fly ash contained sufficient amount of these elements. At the end of experiment the observed maximum concentration of iron was 0.897 mg/g in T₃, while minimum was 0.319 in T₀ and maximum concentration of aluminium was 24.72 ppm in T₃, against the minimum of 1.14 ppm in T₁. This is in agreement with many studies; Kishore et al. (2010) reported that iron in soil increased significantly with increase in percentage of fly ash. Jala and Goyal (2004) also reported that content of Fe in the soil increased substantially from 2180 to 7175 ppm with fly ash application up to 50%. Kumar and Singh (2003) similarly found that Fe and Al increased significantly, up to 4.5 percent of fly ash level due to low soil pH. Kumar (2002) also observed that

the iron content of soil increased to 79.34, 99.58 and 110 % over the control of 6.21% at the rate of fly ash incorporation of 30, 45 and 60%. The increase in the available metals is not only due to fly ash addition, but also due to soil conditions like pH, EC and cation exchange capacity of soil (Dudas, 1981).

Seepage was reduced as the percentage of fly ash application increased which may be due to the reason that fly ash addition generally improves soil porosity, workability and water holding capacity due to decrease in soil bulk density (Rai et al., 2011). Increase in water holding capacity

with fly ash addition into the soil was also found by Sharma et al. (1990). High water holding capacity due to application of fly ash was attributed to its dominant silt and clay fractions (Aggarwal et al., 2009).

5. CONCLUSION

Based on the present study it is concluded that fly ash has notable influence on the soil characteristics like seepage, pH, electrical conductivity, organic carbon, bulk density, Nitrate-nitrogen, silicate-silicon, sodium, potassium, Iron and aluminium.

SUMMARY OF RESEARCH

1. The present investigation has given the importance of usefulness of flyash on the brackishwatersoil of Ratnagiri, in view of the problems faced by Kokan fish farmers.
2. It has availed scientists the opportunity to research more on the usefulness of fly ash in aquaculture ponds with improving condition of soil to give the benefits to farmers

FUTURE ISSUES

There is a need to address the problems encountered during the disposal or reuse of fly ash in various fields. In aquaculture it will be useful where soil water holding capacity and productivity is less.

DISCLOSURE STATEMENT

There is no financial support for this research work from the funding agency.

ACKNOWLEDGMENT

Much thanks to our guide for his constructive criticism, and assistance towards the successful completion of this research work.

REFERENCES

1. Adriano AL, Page AA, Elseewi AC, Chang, Straughan I. Utilization and disposal of fly ash and other coal residues in terrestrial ecosystem: A review., *J. Environ. Qual.*, 1980, 9(3), 333-342
2. Adriano DC, Weber JT. Influence of fly ash on soil physical properties and turf grass establishment. *J. Environ. Qual.*, 2001, 30, 596-601
3. Aggarwal S, Singh GR, Yadav BR. Utilization of fly ash for crop production: Effect on growth of Wheat and Sorghum crops and soil properties. *Journal of Agricultur physics*, 2009, 9, 20-23
4. Alam J, Akhtar MN. Fly ash utilization in different sectors in Indian scenario. *International journal of emerging trends in Engineering and Development*, 2011, (1), 1-14
5. APHA. 21st edition Standard methods for examination of water and waste water. American Public Health Association, American water works association. Water environment Federation, Washington DC, USA.: 30112, 2005
6. Aslam W. Envoimmental pollution from thermal power plants and its control. National workshop on utilization of fly ash, New Delhi: A15-A19, March, 1988
7. Bhattacharya T, Sukalyan C, Gurmeet S. Phytoextraction of few metals from flyash amended soil by *ScripusLittoralis*. In: Recent Research in Science and Technology, 2011, 3(1), 9-10
8. Boyd CE, Tucker CS. Pond aquaculture and water quality management. Kluwer Academic Publication, London: 1998, 44-8
9. Brady NC. The nature and properties of soils, 10th edition. Prentice Hall of India Private Limited. New Delhi: 485, 1995
10. Chang AC, Lund LJ, Page AL, Warneke JE. Physical properties of fly ash amended soils. *J. Environ. Qual.* 1977, 6(3), 267-270
11. Desmukh A, Matti DB, Bharti B. Soil properties as influenced by fly ash application. *J. Soil Crops* 2006, 10, 69-71
12. Dudas MJ. Long term leachability of selected elements from fly ash. *Environmental science and technology*, 1981, 15, 840-843
13. Elseewi AA, Bingham FT, Page AL. Availability of sulfur in fly ash toplants. *J. Environ. Qual.*, 1978, 7, 69-73
14. Grewal KS, Yadav PS, Mehta SC, Oswal MC. Direct and residual effect of fly ash application to soil on crop yield and soil properties. *Crop Res*, 2001, 21, 60-65
15. Inthasan J, Hirunburana N, Herrmann L, Stahr K. Effect of fly ash application on soil properties, nutrient status and envoinment in Northern Thailand. 17th WCSS, 14-21 August, 2002, thiland. Symposium no 24., Paper no. 249: 1-6
16. Jala S, Goyal D. Utilization of fly ash for agronomic advantage. *Proc. In International Conference Bioconvergence 2004* held at Thapar Institute of Engineering and Technology, Patiala, 2004, 18-20. PP:57
17. Jala S. Fly ash an amendment agent for soil fertility. Ph.D Thesis. Department of Biotechnology and environmental sciences, Thapar institute of engineering and technology, Deemed University, Panjab, 2005, P: 325
18. Jhingran VG, Natrajan AL, Banarjee SM, David A. Methodology on reservoir fisheries investigation in India. *Bull. Cent. Ini. Fish. Res. Ins. Barrackpore*, 1969, 12, 1-109
19. Kalra N, Jain MC, Joshi HC, Choudhary R, Harit RC, Vatsa BK, Sharma SK, Kumar V. Fly ash as a soil conditioner and fertilizer. *Bioresource technology* 1997, 64, 163-167
20. kim AG, Kazonich G. The silicate/non-silicate distribution of metals in fly ash and its effect on solubility. *Fuel* 2004, 83, 2285-2292
21. Kishore P, Ghosh AK, Kumar D. Use of fly ash in agriculture: A way to improve soil fertility and its productivity. *Asian Journal of Agriculture Research*, 2010, 4(1), 1-14
22. Kouprianov V, Bashkin V. Environmental impact of heavy metals contained in fly ash emitted from the Thai lignite fired power plant. Department of Mechanical Engineering. Thammasat University, Thailand. 1997, 9, 83-87
23. Kumar D, Singh B. Reclaiming effect of coal fly ash from thermal power plants in sodic soils. *Poll Res*, 2003, 22(3), 403-410
24. Kumar N. Growth responses in crops raised in flyash amended soil. In; Poll res. (4).Scientist, environmental Management group, Central Mining Research Institute.(India), 2002, 410-416
25. Kumar S, Khazanchi AC. Utilization of fly ash- A new approach: National workshop on utilization of fly ash, Roorkee, 2000, 34-39
26. Kumar V, Anadkumar R, Mathur M. Management of fly ash in India: A perspective. 3rd International Conference- Fly ash utilization and disposal. New Delhi, India, 2003, 19-21
27. Kumar V, Singh G, Raj R. Flyash : A material for another Green Revolution. Flyash India. New Delhi.:XII 2.1-XII2.15 at Indore:2003, 126-28
28. Maiti SK, Singh G, Srivastava, SB. Study of the possibility of utilizing flyash for backfilling and reclamation of opencast mines: polt and field scale study with Chandrapur flyash. Flyash India, New delhi. 2005, pp:XII31.1-XII31.13
29. Mittra BN, Karmakar S, Swain DK, Ghosh BC. Flyash- a potential source of soil amendment and a component of

Tekade et al.

Influence of fly ash on soil characteristics of Kharland pond, Ratnagiri (Maharashtra),

Discovery Agriculture, 2013, 1(2), 62-66,

© The Author(s) 2013. Open Access. This article is licensed under a [Creative Commons Attribution License 4.0 \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/).

- integrated plant nutrient supply system. International ash utilization symposium, Center for applied energy research, University Kentucky., Paper 28, 2003
30. Page AL, Elseewi AA, Straughan LR. Physical and chemical properties of fly ash from coal-fired power plants with reference to environmental impacts. *Residue Review*, 1979, 71, 83-120
 31. Phung HT, Lund LJ, Page AL. Potential use of fly ash as a liming material, In D.C. Adriano and I.L. Brisbin (ed.) Environmental chemistry and cycling processes. CONF-760429, U.S. Department of Commerce, Springfield. 1978, pp. 504-515
 32. Rai KA, Biswajit P, Singh G. Assessment of physico-chemical properties of flyash from TISCO power plant, Jamadob, Jharia coalfields, Jharkhand, India., II, 2001, 2-9
 33. Sabhajit N. Utilization of flyash laterite soil in embankment construction in., IGC 2001. The new millennium conference, 14-16 Dec 2001
 34. Sahu GC, Mishra KN. Morphology, Characteristics and Classification of soils of and irrigated river flood plain in the eastern coastal region. *J. Indian Soc. Soil Sci.*, 1997, 45(1), 152-156
 35. Sale YL, David S, Chanasyk A, Naeth AN. Temporal influence of fly ash on soil bulk density and aggregate size distribution. Proceedings of the 20th Annual British Colombia Mine Reclamation Symposium in Kamloops, 1996
 36. Sharma SK, Kalra N. Effect of flyash incorporation on soil properties and productivity of crops: A review. *Journal of Scientific and Industrial Research*, 2006, 65, 383-390
 37. Shivaprasad CR, Reddy RS, Sehgal, Sehgal J, Velayutham M. Soils of Karnataka for optimizing land use. NBSS Publications, Bangalore. 1998, 47, p. 15
 38. Shrivastava S, Sushma D. Effect of fly ash pollution on fish scale. *Research journal of chemical sciences*, 2011, 1(9), 24-28
 39. Snedecor GW, Cochran WG. Statistical methods. Sixth ed. Oxford and IBM publishing Co., New Delhi, 1967, 593
 40. Strickland JD, Parsons TR. A practical handbook of seawater analysis. Second Edition, Bulletin 167. Fisheries Research Board of Canada, Ottawa, 1972
 41. Tandon HLS. Methods of analysis of soils, plants, waters and fertilizers. Fertilizers development and consultation organization, New Delhi, 1972, 58-62
 - Zar JH. Biostatistical analysis. Fourth ed. Tan prints (I) Pvt. Ltd., Delhi, India, 2004, 663